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Toxicity of biomass combustion generated ultrafine particles: evidence from stack-sampled and airborne UFPs

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Background and scope

TOBICUP (TOxicity of BIomass COmbustion generated Ultrafine Particles) project designed to assess the toxicological responses of UFP samples from:
- stack emissions of residential wood combustion units
- airborne UFP samples collected where biomass burning for residential heating is widely used.

UFP sampling

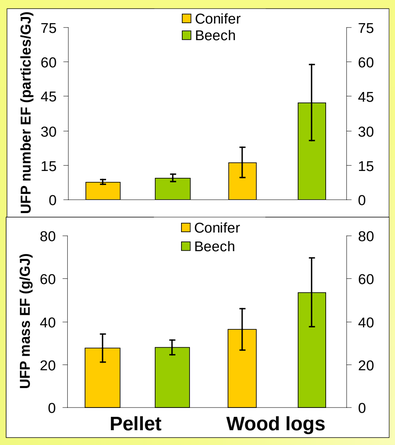
- UFP stack samples generated by wood (beech and fir) combustion in a 11 kW pellet stove (automatically stoked) and in a 8 kW wood log stove (manually stoked) collected during combustion tests intended to simulate real-world combustion cycles
- Airborne UFP samples collected during monitoring campaigns carried out at a small alpine town (Morbegno) in Northern Italy, where wood burning is largely diffused for domestic heating in winter. Integrated UFP samples were collected both in wintertime (over three/four days) and summertime (seven days).
- Parallel multistage impactors equipped with different collection substrates, depending on the subsequent analysis to be performed.

Chemical and biological analyses

- Determination of elemental composition (ICP-AES), inorganic ions (IC), anhydrosugars (HPAEC-PAD), total organic carbon (TOT), PAHs (GC-MS)
- Investigation of pro-inflammatory cytokine interleukin-8 (IL-8) induction in two human cells lines (THP-1 and A549), used as surrogates of alveolar macrophages and lung epithelial cells
- UFP-induced oxidative stress and genotoxicity investigated in A549 cells by alkaline comet assay and γ-H2AX
- NIES certified diesel exhaust particles (DEP) used as reference for biological effects

Results – UFP stack samples

UFP emission factors



Flue gas concentrations (@NTP,13% O_2)

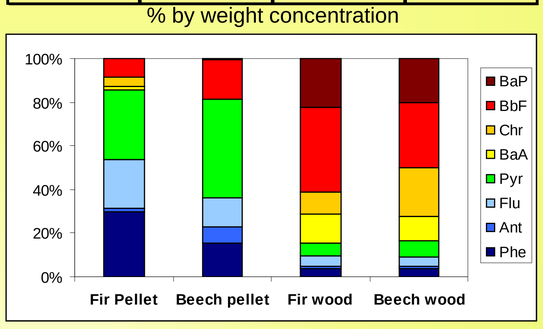
Pellet
12-56 mg/m³
5-16 ·10⁷ #/cm³
MGD 35-71 nm

Wood logs
32 - 107 mg/m³
23-60 ·10⁷ #/cm³
MGD 51-107 nm

PAHs concentrations and fingerprints

Pellet		Wood logs	
Fir	Beech	Fir	Beech
0.01 ± 0.01	0.01 ± 0.01	0.12 ± 0.03	3.24 ± 0.63

% by weight concentration



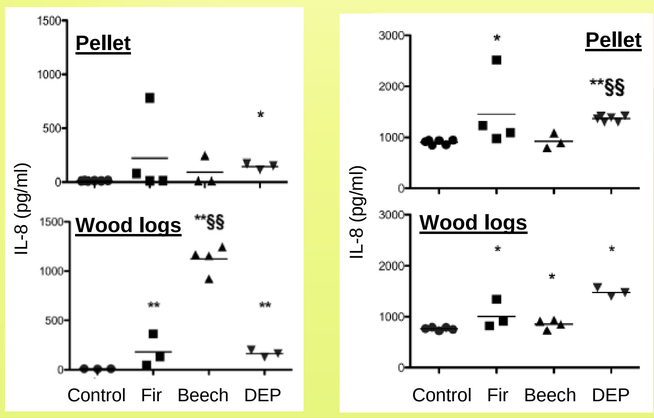
Cyto- and genotoxic effects (A549)

Mass dose based relative toxicological responses					
Fuel & Stove	genotoxicity γH2AX	genotoxicity comet test	oxidative stress ROS	oxidative stress RNS	cytotoxicity MTT
Fir pellet	1.6	1.1 *	1	1.1	1
Beech pellet	1.3 **	1 ***	1.6	1	2.3 **
Fir Wood	1.7 **	2 ***	1.2	1.1 *	2.6 *
Beech Wood	1 **	1.1 **	1.4 *	1.2 *	2.1 *

Energy-weighted relative toxicological responses					
Fuel & Stove	genotoxicity γH2AX	genotoxicity comet test	oxidative stress ROS	oxidative stress RNS	cytotoxicity MTT
Fir pellet	1.4	1.3	1.2	1.3	1
Beech pellet	1	1	1	1	2
Fir wood	1.8	2.9	1.1	1.5	3.2
Beech wood	2	3.1	2.5	3.2	4.8

* p<0.05
** p<0.01
*** p<0.001
vs. control
Cells treated for 24h with 100 µg/ml$_{medium}$

Inflammatory effects (THP-1, A549)



* p<0.05
** p<0.01
vs. control
§ p<0.05
§§ p<0.01
vs. UFP or DEP treated cells

Results – airborne UFP samples

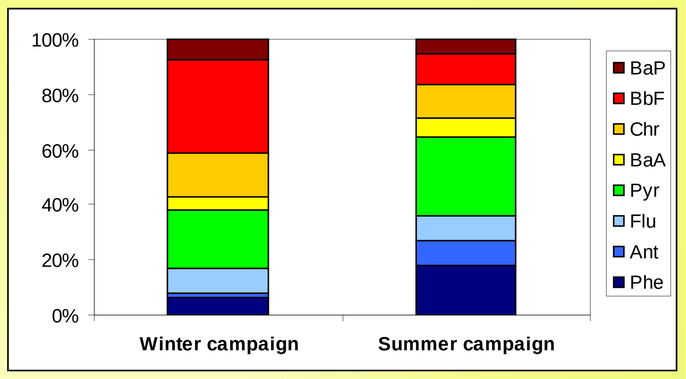
UFP ambient concentrations

Winter	Summer
Average:	
2.2 µg/m³	2.0 µg/m³
Range:	
1.6-3.2 µg/m³	1.0-3.1 µg/m³

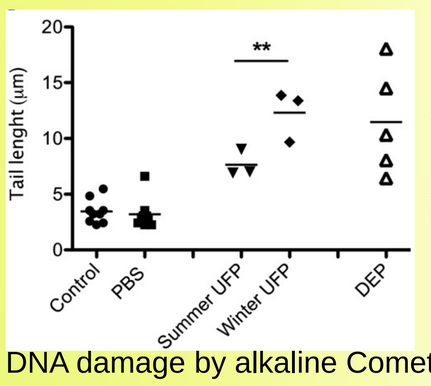
PAHs concentrations

Winter	Summer
2.3 ng/m³	0.3 ng/m³

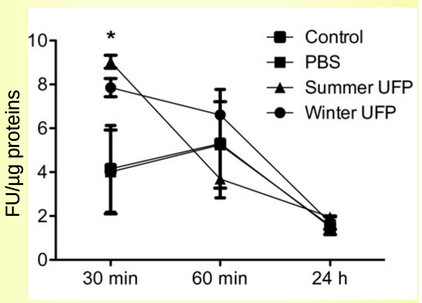
PAHs fingerprintss

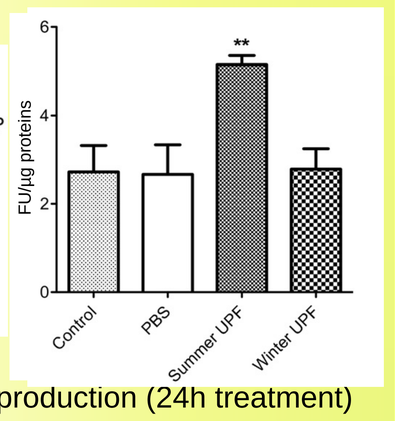


Cyto- and genotoxic effects (A549)



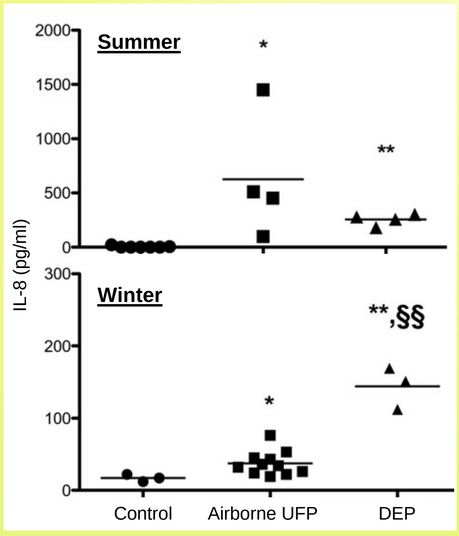
DNA damage by alkaline Comet assay

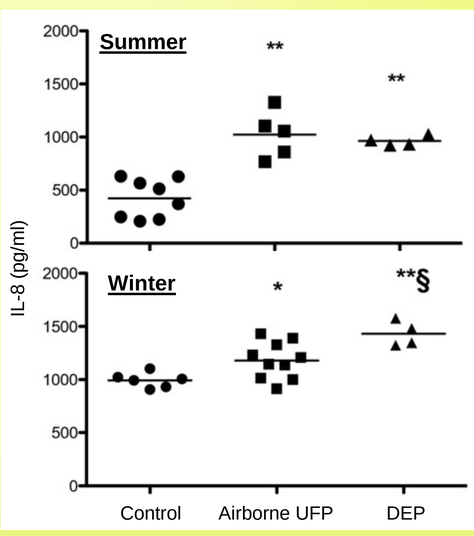




ROS and RNS production (24h treatment)

Inflammatory effects (THP-1, A549)





Conclusions

- UFPs from wood logs combustion displayed stronger genotoxic and inflammatory effect than UFPs from pellet combustion
- Beech wood logs induced higher IL-8 release in THP-1 cells
- Airborne UFPs were able to stimulate an inflammatory response: summer UFPs more active in inducing IL-8 release in both cells lines, but the release was overall similar to the one observed with DEP
- Genotoxic effects induced by winter UFPs were higher than those induced by UFPs sampled in summer
- Genotoxic effects driven by PAHs both in stack and airborne UFP samples

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